coefficient of elasticity, the elastic limit being close to the breaking point, and much greater than the tension put upon the strings during the operation of tuning. Secondly, it must be of uniform diameter and uniformly round in cross sections, otherwise the over-tones to which is due the tone quality will not be perfectly secured; thirdly, it must have permanence, that is to say, it must not stretch under continued stress.

The number of vibrations per unit of time, corresponding to the fundamental tone produced by a string, varies inversely as the length of the string, inversely as the square root of its weight, and directly as the square root of its tension. If a wire be stretched between two points *A* and *B* (see accompanying diagram), and plucked or struck, it will vibrate above and below the line *A B*, giving what is known as a fundamental tone. This fundamental tone is without character, and would sound the same in all instruments, so that one could not distinguish whether it came from a violin or a piano.

In addition to its fundamental vibration between its points of attachment, the string undergoes a series of sub-vibrations, above and below its own normal curve, which it will pass at certain points, "nodes," dividing it into equal parts. Thus, in the accompanying sketch, *A*, *C*, *B* and *A*, *D*, *B* represent the fundamental vibrations, and *A*, *E*, *C*, *F*, *B* the first sub-vibration intersecting the fundamental vibration at the node *C*. Again, the string may vibrate in three parts, four parts, five parts, etc. The production of the proper sub-vibrations, and the determination of their power relative to the power of the fundamental vibration, constitutes one of the most abstruse problems in the art of piano making; for the effect of the sub-vibrations is added to the effect of the fundamental vibration, and their total effect is heard in the distinctive quality or "tone color," as it is called, of the instrument. The sub-vibrations are known as the upper partials or over-tones, and generally speaking, they are harmonious with one another and with the fundamental tone.

The over-tones which correspond to the division of the string into seven or nine aliquot parts, however, are inharmonic, and in order to destroy them the hammers are so placed that they will strike at one-eighth of the length of the string. The width of the striking surface of the hammer is sufficient to intercept and dampen out the seventh and ninth upper partials, leaving only those which are harmonic. In the accompanying diagram, the sinusoidal curve representing the condensation and rarefaction of the air produced by the fundamental tone is shown by a heavy dotted black line, and the effect produced by the first, second, and third upper partials by fine lines. The effect of the latter upon the fundamental is to produce the irregular heavy final curve, which is shownhere by a heavy black line. It must be understood that three only of the upper partials or over-tones are shown, whereas they may run up to the thirty-fourth or thirty-sixth, all tending to give fine quality to the resultant tone.

In laying out the "scale," a certain standard tension (in the Knabe piano about 141 pounds) is adopted for all the strings, and it is invariable. The variable elements are the weight of the wire and its length. The scale starts in the treble with a short length of about 55 millimeters, and if the same weight of wire were used throughout, the lowest bass strings would have to be 32 feet in length, which is, of course, impossible. The piano builder chooses, therefore, the greatest length of bass string compatible with the size of the piano which he intends to build, and then to obtain the correct pitch, he winds on a sufficient weight of copper or other wire to reduce the pitch to the proper standard. The number of vibrations varies from 26 per second in the lowest bass string, to 4,136 in the highest treble string per second.

(*To be continued.*)

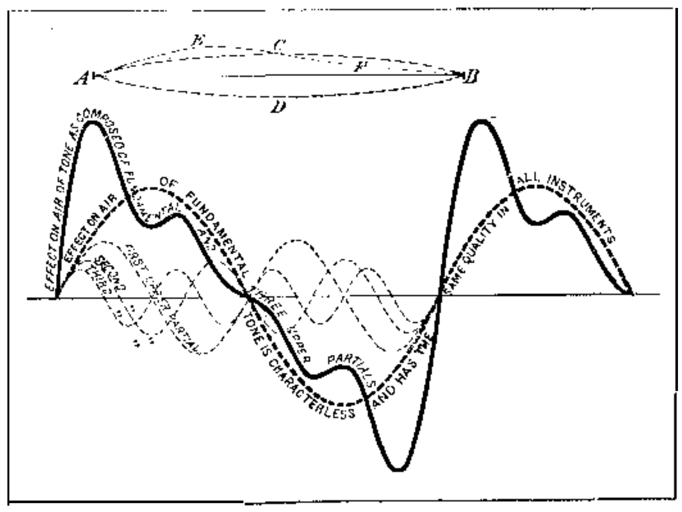


Diagram Showing Effect of the Upper Partials in Modifying the Fundamental Tone.

EARTHQUAKE OBSERVATIONS.

BY PROF. EDGAR L. LARKIN.

A cemetery filled with monuments, columns, and obelisks is a capital place to study the effects of an earthquake. Amplitudes and azimuths of disturbed monoliths and pillars reveal at once the action of the earth upheavals. I had no instruments with which to measure, so had to make estimates.

Laurel Hill Cemetery I found a field of distorted, shifted, turned, cracked, overthrown, and ruined columns, pillars, shafts, capitals in white marble, gray granite, and other materials. Angels' wings were broken, sculptures were round about, and heavy bases were twisted out of their original positions. At first I noted distortions on both sides of an avenue of tombs. Here are directions in which the tops of fallen columns and monuments were pointing along either side, in a distance of 150 feet: N. 1, S. 2, E. 9, W. 5, N.E. 4, N.W. 5, S.E. 5, S.W. 6. From this I thought that the chief distortion was toward the east. Then facings of those that were skewed around on their bases, but not overthrown, were noted, as follows: N. 1, S. 1, E. 2, W. 1, N.E. 4, N.W. 0, S.E. 2, S.W. 1. All these had been twisted around against intense friction at their bases. The one marked N. originally faced eastward, and the one shown as facing S. once faced westward. I examined many others, hoping to make order out of chaos, or find a general trend in direction, but could not. The conclusion reached was that the monuments were thrown over and twisted in every direction.

The Oddfellows' Cemetery was explored. This is more modern than Laurel Hill; the monuments are higher and heavier. They were fastened down by lead in some cases. The most complete confusion reigned. The displacements likewise were in every direction. An observer with instruments, upon making surveys during a month, might find a majority of fallen columns pointing one way, or facings, but it is doubtful. The earth's surface surely moved in every direction. As nearly every brick and stone building was destroyed, they could not be studied. The great Fairmount Hotel has rents in the corners, and several high up, along near the middle of the façades. The new $5,000,000 post office is torn near the corners. The towering steel and stone Spreckels Building stands as a skeleton, but looking down on a wilderness of ruins of all old-type buildings. For the new city will be erected around ribs of rigid steel. The accompanying diagrams show roughly the distortions in the cemeteries. The line N.S. is due north and south, in cuts Nos. 1 and 2. Twistings of obelisks that did not fall range from five to seventy degrees in all directions from their original foundations. My impressions gained in the cemetery were confirmed upon receipt by mail of the seismograph shown on page 419. It was sent me by F. M. Clarke, steward and executive officer of the California Veterans' Home, Yountville, Napa County. My thanks are hereby extended to him for the faithful record. It indeed shows that the ground moved in every possible direction. On leaving the cemetery I wrote an article for the papers, saying that it was a circular disturbance, and the graph reveals a circle near the center. Mr. Clarke says: "The first movement had a N. and S. direction, but was swiftly compounded with a circular, twisting movement, accompanied with severe upward thrusts. The first movement was decidedly wave-like; then a cessation, followed by the severe twist." Napa is 45 miles north of San Francisco, and San José, 50 south. Both were destroyed.

Mr. Edward Pickersgill, Alameda, Cal., sends me a series of photographs of great upheavals, distortions, and displacements of the ocean shore, four miles from Colma. Vast banks of sand slid into the sea, and a new high point of land was formed as shown on page 419. A place where gas escaped from soft mud is also shown. The soil is a foot or more high, and six wide.

Without doubt, gas had to do with the great earthquake. Newspaper reports say that from April 18, 5:18:57 A.M., to April 26, 3:15 P.M., thirty-two shocks left their imprint on the seismograph at Berkeley, and that twenty-six occurred on the first day, the 18th. I felt the sharp shock that came on the 20th, 4:34:17 P.M., in a three-story frame building. It was my fourth earthquake. The priceless collection in the magnificent Lick Academy of Sciences vanished. All the replicas of historic, paleontological and geological finds were consumed; also early Spanish records of exploration. The great libraries and many private collections of literary treasures exist only in cherished memories.

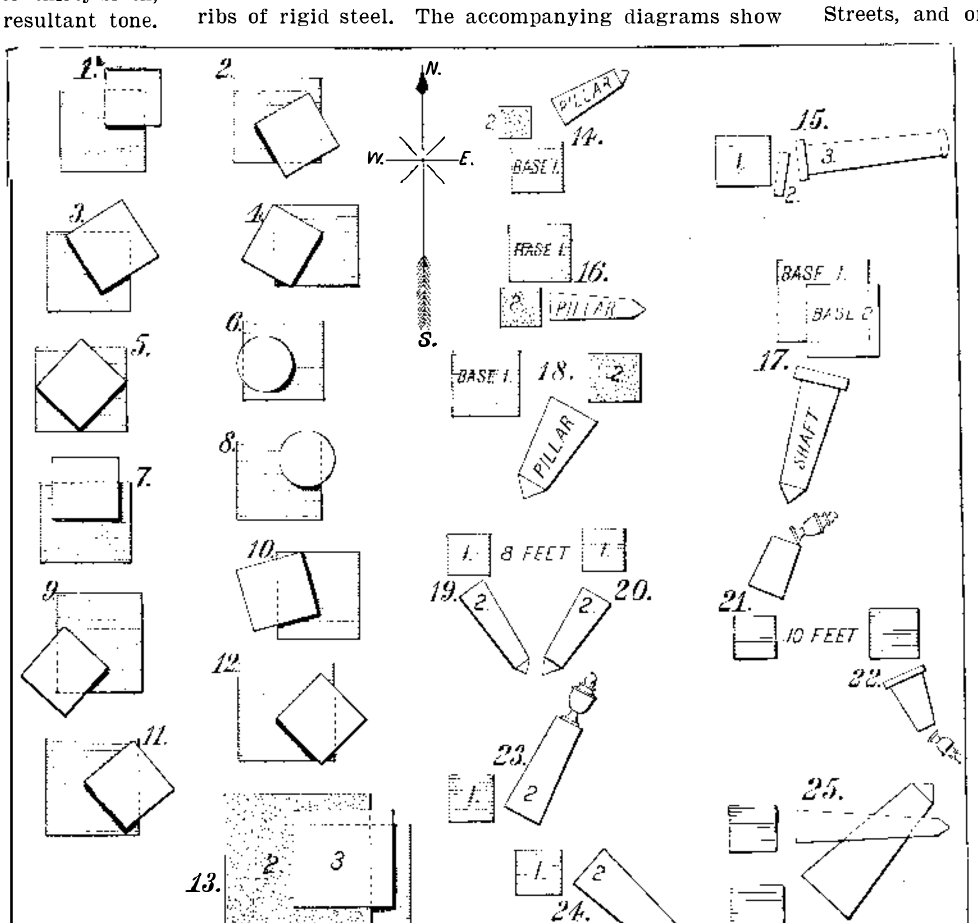
Mt. Lowe Observatory, Cal.

EFFECTS OF THE EARTHQUAKE AND FIRE UPON THE CITY OF SAN FRANCISCO AND ITS BUILDINGS.

BY ARTHUR INKERSLEY.

About ten days after the San Francisco earthquake, which occurred at 5:13 on the morning of Wednesday, April 18, the city engineer sent out three parties for the purpose of ascertaining whether or not the whole city had sunk as a result of the shock. Many places were found where the ground had sunk considerably; especially on Valencia Street between 19th and 20th Streets, at the easterly end of Market Street near the ferry depot, on Howard Street between 17th and 18th Streets, on Van Ness Avenue from Vallejo to Green Streets, and on Folsom Street near 17th Street. The sinking is almost wholly on made ground in the lower parts of the city. At the southeast corner of the United States post office on Mission and Seventh Streets, there is a depression and a corresponding raising up of about four or five feet. That part of the post office was built over an old swamp. The building retained its position, but the concrete sidewalk pulled away from it, leaving a gap of six to ten inches. The city engineer's conclusion is that the city as a whole did not sink. There was no distinct subsidence of any considerable portion of the peninsula.

The disturbance of the earth's crust on Wednesday morning, April 18, in San Francisco and its vicinity was really inconsiderable. The vibration was sufficiently great and sustained to shake down chimneys, bad masonry, and old frame buildings on rotten or insecure foundations. According to Prof. O. A. Leuschner, of the astronomical observatory of the University of California at Berkeley, Alameda County, the damage caused would have been vastly more serious had the vibrations not been distributed over so many seconds. If the shocks had been instantaneous, very much greater ruin would have resulted. The standard clock of the students' observatory stopped at 5:12:38 A.M. Pacific time, some less severe temblors being recorded at 5:12:03. The earthquake came chiefly in two shocks, the first series of vibrations



Figs. 1 to 12 show the displacements of monuments in San Francisco cemeteries. The larger squares are bases of stone resting on the ground. The smaller squares and the two circles (Figs 6 and 8) are bases of high monuments. The greatest shifting measured was 10½ inches. The lateral movements appear to have been in all directions. Fig. 13 shows a double displacement of two bases and monument. The square 1 is a large granite base; the square 2 is a second stone upon which the column 3 rested. Figs. 14 to 25 indicate the positions of overthrown monuments. The two low monuments with urns (Figs. 21 and 22) could not have been thrown by the same oscillations of the earth.

CEMETERY MONUMENTS OVERTHROWN BY THE EARTHQUAKE.